ORIGINAL ARTICLE

Why Physics in Medicine?

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Abstract

Despite its crucial role in the development of new medical imaging technologies, in clinical practice, physics has primarily been involved in the technical evaluation of technologies. However, this narrow role is no longer adequate. New trajectories in medicine call for a stronger role for physics in the clinic. The movement toward evidence-based, quantitative, and value-based medicine requires physicists to play a more integral role in delivering innovative precision care through the intentional clinical application of physical sciences. There are three aspects of this clinical role: technology assessment based on metrics as they relate to expected clinical performance, optimized use of technologies for patient-centered clinical outcomes, and retrospective analysis of imaging operations to ensure attainment of expectations in terms of quality and variability. These tasks fuel the drive toward high-quality, consistent practice of medical imaging that is patient centered, evidence based, and safe. While this particular article focuses on imaging, this trajectory and paradigm is equally applicable to the multitudes of the applications of physics in medicine.

Key Words: Evidence-based imaging, value-based, imaging technology, medical, physics, radiology

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Radiology and physics have always had a symbiotic relationship. Beginning on November 8, 1895, when the German physicist and first physics Nobel laureate Wilhelm Roentgen discovered the mysterious "x" rays, physics has had a central role in the development and advancement of radiology. Although the science of medical physics and the clinical practice of radiologic interpretation have followed separate professional trajectories, they remain tightly connected. Over the decades, medical physics has enabled continuous advances in imaging and its safe and effective use. At the same time, medical physics has drawn its meaning and raison d'être from clinical radiology. The clinical practice of radiology rests on a physics foundation, whereas medical physics exist to serve clinical interpretation. The relationship between radiology and physics has thus been mutual and essential for both disciplines for the overall goal of medicine: fostering human health. In the current health care landscape of enhanced and diverse imaging options, optimized and evidence-based use of the technology cannot be assumed. Physics has great potential to move beyond compliance and safety testing toward intentional evidence-based use of the technology to serve clinical care.

CULTURAL TRAJECTORIES IN MEDICINE CALL FOR A CLOSE RELATIONSHIP

In recent years we have seen a drive toward evidence-based medicine [1], ensuring that clinical practice is informed by science. Physics, as a foundational scientific discipline, can naturally contribute to this goal within the practice of radiology. Likewise, the current emphasis on comparative effectiveness and meaningful use puts extra scrutiny on the actual, as opposed to presumed, utility of technology and processes [2-5]. This highlights the need for a scientific approach to practice, again with an obvious role for physics. In line with these moves, medicine is also seeing a slow shift toward quantification, using biometrics that personalize the care of the patient in numerical terms [6]. This provides for better evidence-based practice for both diagnostic and interventional care. Again, physics is a discipline grounded in mathematics and analytics with direct potential for the practice of quantitative

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imaging. Finally, the mantra of value-based medicine [7] highlights new priorities for safety, benefit, consistency, stewardship, and ethics. To practice value-based care, the value needs to be quantified, which again brings forth the need for numerical competencies, such as physics can provide. These trends in medicine call for a closer exchange between physics and radiology.

Concurrent with the trajectories of evidence-based, quantitative, and value-based medicine is the significant promise of artificial intelligence (AI) in medicine [8]. In the future, many routine tasks performed today by radiologists and medical physicists may be delegated to computational systems that are able to offer intelligent characterizations of images and imaging systems. Although this will certainly be disruptive to the practice of radiology and medical physics, it is best recognized as an opportunity. AI is definitely coming to medical imaging, but if implemented well it would not replace radiologists or medical physicists but become a tool for our collective use. This will create yet another context for collaboration between radiologists and physicists. The characterizations AI can provide may presumably be superior to those of an individual practitioner because they are based on large aggregates of information representing the best of imaging physics and clinical practice. Curation of such aggregate data across the heterogeneity of imaging technologies is a monumental task. Given their skills in numerical analysis and clinical integration, physicists can significantly aid in the curation of aggregate data, in the use of imaging models to facilitate data mining, and thus in the meaningful implementation of AI technology into radiology practice. Likewise, using their skills in clinical informatics and image interpretation, radiologists are uniquely qualified to curate imaging data and ensure their quality and integrity for use in data mining.

NEW TECHNOLOGIES CALL FOR A CLOSE RELATIONSHIP

Medical imaging has had the enviable status of maintaining perpetual technological innovation throughout its history. Every time we feel settled with a particular technology, a newer one is around the corner. Let us highlight just a few recent developments, in no particular order: CT has seen major advances in the use of statistical reconstructions, novel geometries, and spectral imaging. Mammography is experiencing a strong shift toward tomosynthesis and computer-aided diagnosis. MRI is undergoing major development in new pulse sequences, advanced reconstruction, and MR quantification. Nuclear imaging is moving toward hybrid imaging and molecular precision. Radiography and fluoroscopy are witnessing a significant move toward wireless digital technology and cone-beam multidimensional imaging. Ultrasonic imaging is moving toward 3-D imaging, elastography, and new contrast-based acquisitions. And medical displays are showing a shift toward the use of color, multidimensional rendition, and portable monitors. What are the implications of these advances in the practice? How can we ensure that well-intentioned and well-designed technologies are used effectually for the improvement of patient care without compromising the consistency of care? These are questions that can only be answered using an integrated strategy that includes both physics and radiology.

RADIOLOGIC COMPETENCY CALLS FOR MEDICAL PHYSICS

Radiologists are not just physicians: they are physicians with special added expertise in interpreting medical images. To do so effectively and accurately, radiologists need not only specialized medical competency but also technical competency. This technical competency often distinguishes a radiologist from other physicians who use images for their practice. It consists of understanding (1) the foundations of contrast formation in a given imaging modality, (2) the technological components that enable the acquisition of an image, (3) the modality's operational parameters and their influence on image quality and patient safety, and (4) how to practice imaging within the constraints of the imaging modality and the needs of the indication [9]. These elements are cornerstones of the physics competency expected from radiologists by the ABR. The experts of this domain are medical physicists, who can provide training for junior practitioners in which their technical expertise is matched with the effective use of adult learning methods and with an understanding of the different norms and culture of the two disciplines (a challenge for any interdisciplinary exchange).

NEW PHYSICS FOR NEW TECHNOLOGIES AND NEW PRIORITIES

Current radiologic practice is based heavily on ensuring compliance with regulations and guidelines. This is necessary, but it is not enough. The newest guidelines highlight this limitation [10,11]. Physics is most relevant to the extent it seeks to address clinical needs and limitations. Regulations, by necessity, are always a step behind clinical opportunities, needs, and realities. The